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ASSESSMENT OF INNOVATIVE ACTIVITY OF REGIONS IN THE RUSSIAN FEDERATION

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Abstract

It is shown that a factor of the number of created new production technologies by the regions of the Russian Federation is the size of a common space of innovation, which is determined by the number of potential links between organizations involved in research and innovation active enterprises in the region. Estimates of the efficient use of this resource are got. An agent-based model for the assessment of innovative activity of regions of the Russian Federation is built. The model process of technological innovation is due to the efficient use of innovation's space and a set of the regional economy characteristics.

Keywords: *regional economy, innovation system, innovations' space, new technologies, efficiency, agent-oriented modeling.*

JEL classification: C12; C51; R15;
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1. INTRODUCTION

It is universally acknowledged that innovative development of Russia is the only real alternative to the energy-based development scenario, both for the country overall and for its separate regions too. The today's model of regional innovative development in the leading countries of the world is often based on the approach which assumes cooperation of public bodies, businesses and universities. The key preconditions for this cooperation to be efficient are as follows: favourable business climate in the country overall and in its separate regions; well developed applied sciences, including successfully functioning engineering bureau, project institutes, experimental plants etc.; availability of universities with the entrepreneurial model of management (which assumes three functions being in parallel – education, research and business); availability of investors' network; well developed and really functioning mechanisms for private and public investments' attraction to the most innovative projects; developed infrastructure overall (including, first of all, technoparks and business incubators). This approach in general forms the basis for the traditional innovation model which is currently being implemented in such countries as the US, UK, Germany, France and some other. This model of full innovation cycle – from the stage of an innovation idea emergence to the stage of mass production of a readymade product – can be also introduced into Russian experience, primarily because there is an important success factor for it – availability of well developed fundamental sciences. However, direct copying of foreign experience while trying to finance the innovative projects using the state funds would never solve the task of intensified national technological development.

Vast numbers of literature sources clearly show that the key element of the innovative processes is subjects' ability to connect and cooperate within a regional innovation system

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(Bazovyi doklad…, 2009; Golichenko et al., 2012; Gorizonty innovatsionnoi ekonomiki…, 2010; Gurunyan, 2011; Efimova, 2012; Lapaev, 2012; Larina, 2012; Makoveeva, 2012; Polterovich, 2010; Rumyantsev, 2013; Simachev, 2012; Shchepina, 2011).

Establishing the quantitative features of such connections and cooperation belongs to the most complex tasks in the analysis of innovation processes. Thus, the aim of this study is to consider the potential connections between the subjects of Russian regional innovation systems – organizations generating new knowledge, including innovation ideas, engineering bureaux, project institutes and innovatively active enterprises which apply this new knowledge while developing innovations. We pose and consider in details the hypothesis that these connections are some sort of resource for the invention process, and the number of innovations, created in a particular region, depends on the share of potential relations between research organizations and enterprises in a region included into the regional innovation system.

2. GENERAL PROVISIONS AND KEY NOTIONS

In this study as the sources of innovative ideas we see organizations carrying out research projects and thus generating new knowledge. To the group of such organizations here belong institutes within the structure of the National Academy of Sciences, universities and other research organizations. Innovations are viewed here as the result of these organizations' cooperation leading to new knowledge generation. Conditions for this form of cooperation and its results and efficiency are predetermined by the institutional environment, shaped and regulated by the state.

General infrastructure of innovations – the total number of organizations generating new knowledge and being innovatively active, participating in innovations' creation to some extent or forming the institutional environment, and thus also impacting the process of innovations' generation.

The overall space of innovations – the totality of potential connections between the organizations generating new knowledge and innovatively active enterprises.

The volume of the overall space of innovations – the number of potential relations between the organizations, generating new knowledge and innovatively active enterprises.

The whole totality of generated innovations can be tentatively divided into several types, among which special place belongs to new production technologies. Among other types of innovations we can also differentiate organizational, marketing and other types of innovations. All experimental calculations further in this study have been carried out solely for new production technologies. And such used in this article notions as "general infrastructure of innovations", "overall space of innovations", "the volume of overall space of innovations" etc. are used in the context of this specific type of innovations. Along with the already mentioned above general notions, we will also operate such notions and constructions as "infrastructure for technological innovations", "the space of technological innovations" and "the volume of technological innovations' space".

2.1 Model

Let S_i be the number of organizations creating new knowledge in region i;

B_i - the total number of innovatively active enterprises in region i.

Then the number of potential connections between organizations, generating new knowledge, and innovatively active enterprises, that is, the volume of the overall space of innovations $\overline{V_i}$ in region i is limited by the value $\overline{V_i} = S_i B_i$.

Let us specify the innovations of particular type. Let α_i be the share of research organization generating innovation of a particular type in region i in the total number of organizations engaged in research activities; β_i is the share of innovatively active enterprises in region i, connected with research organizations in the process of innovation creation, in the total number of innovatively active enterpises in the same region. Then the volume V_i of the innovative space of a given type in region i would be determined as

$V_i = \alpha_i S_i \times \beta_i B_i = \alpha_i \beta_i S_i B_i = w_i \overline{V_i}$, where $w_i = \alpha_i \beta_i$ - the share of innovation space volume for the innovations of a given type in the overall volume of innovations space.

Let us introduce a productin function that describes the dependence between the number of created innovations of a given type and the number of research organizations as well as the number of cooperating with them innovatively active enterprises which can be treated here as resources for the innovative process. Let Q_i be the number of innovations of a particular type, created at a time unit in the region i. Then, $Q_i = f(\alpha_i S_i, \beta_i B_i)$. For simpler analysis we employ here a power function $Q_i = a(\alpha_i S_i)^{\delta_S} (\beta_i B_i)^{\delta_B}$. Here we introduce the normalizing condition $a = 1$. That is, in the considered period of time one innovation is the result of interaction between a research organization and a regional enterprise.

Assumption 1. If the condition $\delta_S = \delta_B = \delta > 0$ is met, (1)

then the number of innovations of a specific type generated in a region directly depends upon the volume of the overall innovation space.

If the condition (1) is met, it means that elasticity of the created innovations' number by the number of research organizations is equal to the elasticity of the number of generated innovations by the number of enterprises. Assumption 1 means that while meeting the condition (1) the result of innovative activity is determined by the number of potential connections between the organizations, generating new knowledge, and the innovatively active enterprises of a region, that is, by the volume of overall innovative space.

Indeed, if the condition (1) is met – then after the transformation we get:

$$Q_i = (\alpha_i \beta_i)^{\delta} (S_i B_i)^{\delta} = w_i^{\delta} \overline{V}_i^{\delta}.$$

In this case the production function would take the following form:

$$Q_i = d\overline{V}_i^{\delta},$$

where $\overline{V_i} = S_i B_i, d_i = w_i^{\delta}$.

Therefore, in case if the condition (1) is met, the production function is reduced to the type at which the resource for innovation production of any particular type is the volume of the overall innovation space, that is, the number of potential connections between research organzations and innovatively active enterprises.

Hypothesis 1: the number of specific-type innovations generated by the regions of Russian Federation is directly dependent upon the volume of overall innovation space.

Testing Hypothesis 1 is basically reduced to testing whether condition (1) is fulfilled. Let us introduce the following: $\delta_S = \delta, \delta_B = \delta + \eta$, and note that η can have both positive and negative signs. Then, after the transformation we get:

$$Q_i = (\alpha_i \beta_i)^{\delta} (S_i B_i)^{\delta} (\beta_i B_i)^{\eta}.$$

In this case the production function may be presented in the following form:

$Q_i = b_i \overline{V}_i^{\delta} B_i^{\eta}$, где $b_i = (\alpha_i \beta_i)^{\delta} \beta_i^{\eta}$.

Empirical testing of Hypothesis 1 is then reduced to testing the statistical hypothesis[3]:

H_0^1: $\eta^2 = 0$.

Assumptions:

1) α_i β_i are random values;

2) the share $w_i = \alpha_i \times \beta_i$ belonging to the innovation space of a specific type in the overall space of innovations can be presented as $w_i = \overline{w} e^{\varphi_i - \psi_i}$, where $\overline{w}$ is a constant value and φ_i is a random value which has normal distribution with zero expectation, ψ_i - nonnegative random value, having half-normal distribution.

If Hypothesis 1 is valid, then

$Q_i = d\overline{V}_i^{\delta} = w_i^{\delta}\overline{V}_i^{\delta} = e^{\delta \ln w_i}\overline{V}_i^{\delta} = e^{\delta(\ln \overline{w} + \varphi_i - \psi_i)}\overline{V}_i^{\delta} = \overline{w}^{\delta}\overline{V}_i^{\delta} e^{v_i - u_i}$,

where $v_i = \delta\varphi_i$ is a random value, having normal distribution with zero expectation;

$u_i = \delta\psi_i$ is a nonnegative random value, having half-normal distribution.

The random component $v_i - u_i$ demonstrates the results of the impact on the process of innovations' generation of the uncertainty factors and efficiency factors. In order to model the results of the uncertainty factors' impact we use the normally distributed random value v_i with zero expectation $v_i \in N(0, \sigma_v^2)$. For modelling the results of the efficiency factors' impact we use the independent from v_i nonnegative random value u_i which has the truncated in zero normal distribution with zero expectation $u_i \in N^+(0, \sigma_u^2)$.

According to the concept of stochastic frontier (Kumbhakar, Lovell, 2004), $\overline{w}$ is the expected maximum share from the overall innovation space, used by the innovatively efficient regions and determining the stochastic frontier production function $Q_i = \overline{w}^{\delta}\overline{V}_i^{\delta} e^{v_i}$.

Stochastic production function $Q_i = \overline{w}^{\delta}\overline{V}_i^{\delta} e^{v_i - u_i}$ can be presented as $Q_i = (\overline{w} e^{-\psi_i})^{\delta}\overline{V}_i^{\delta} e^{v_i}$. Then the random value $\tilde{w} = \overline{w} e^{-\psi_i}$ assumes the interpretation of what is the share of the overall innovation space, used by a region for creation of innovations of a specific type. Note here that for any region the inequality $\tilde{w} \le \overline{w}$ is applicable.

The function $Q_i = \overline{w}^{\delta}\overline{V}_i^{\delta} e^{v_i - u_i}$ in its logariphmic form looks like:

$$\ln Q_i = c + \delta \ln \overline{V}_i + v_i - u_i \quad (2)$$

From the condition $\overline{w} \le 1$ it follows that $c \le 0$. Once the paratemeters $c, \delta, \sigma_v^2, \sigma_u^2$ are assessed, we get $\overline{w} = e^{c/\delta}$. Thus, we are able to assess the mathematical expectation (Battese, Coelli, 1988):

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[3] Establishing connections between research organizations and enterprises as well as innovations creation are treated here as random processes. Thus, the number of innovations, created during a certain period of time, is also random.

$$TE_i = E(e^{-u_i} \mid v_i - u_i) = \frac{\Phi(\tilde{\mu}_i / \sigma_* - \sigma_*)}{\Phi(\tilde{\mu}_i / \sigma_*)} \exp\{\frac{1}{2}\sigma_*^2 - \tilde{\mu}_i\},$$

where $\tilde{\mu}_{it} = -(v_i - u_i)\sigma_u^2 / \sigma^2$, $\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

In this case TE_i can be treated as the estimate of efficiency for region's use of the overall innovation space at creation of innovations of a specific type. As the estimate of $\tilde{w}_i$ in this study further we use $(\overline{w}^{\delta} \times TE_i)^{1/\delta}$. Then $\tilde{V}_i = \tilde{w}_i \overline{V}_i$ will be the estimate of space volume for innovations of a particular type. Dynamics of innovative activity and of the number of created innovations for the totality of regions will depend upon the dynamics of the parameter $\overline{w}$. Growth of $\overline{w}$ determines the growth of the stochastic frontier $Q_i = \overline{w}^{\delta} \overline{V}_i^{\delta} e^{v_i}$, that is, the increase in the expected number of innovations, created by innovatively efficient regions. The dynamics of $\overline{w}$ is determined by the ratio of the parameters c and δ since $c \le 0$, and with the growth of δ the value of $\overline{w}$ is growing too; while with the growth of c the value of $\overline{w}$ is growing again. Under opposite directions of changes in c and δ, the dynamics of $\overline{w}$ is determined by the dynamics of the ratio c / δ. Thus, in case the hypothesis 1 is correct, we can evaluate the share of the overall innovation space a particular region is used in creation of innovations of a particular type, which basically means the space for innovations of a particular type. Further, testing the hypothesis 1 and calculations of this share of innovations space for various regions of the Russian Federation are carried out using the official data of RosStat (state statistics office in Russia) concerning the number of developed new technologies, the number of organizations engaged in active research and the number of innovatively active enterprises. The period under investigation is 2008 to 2012.

2.2 Original data

Table 1 below presented the indicators which we further apply to test our Hypothesis 1 and also in calculations of the overall space of innovations by Russian regions. In the same table one can also see the official sources of information we have used for this.

Table 1. Indicators and official sources of information

Symbol	*Indicator*	*Information source*
teh_i	The number of new production technologies, invented in a particular region	(Razrabotannye..., 2013)
P_i	The total number of enterprises in a region	(Chislo predpriyatiy..., 2013)
I_i	The share of innovatively active enterprises in their total number in a region	(Chislo predpriyatiy..., 2013)
S_i	The number of organizations in a region, engaged in research	(Organizatsii..., 2013)

In the used here notations the number of innovatively active enterprises of the region is defined as $B_i = P_i \times I_i$.

Further in the text we also use the following notations:

$teh10_i$ – the average number of technologies created in a region during one year (the overall period of observations is from 2008 to 2010)[4];

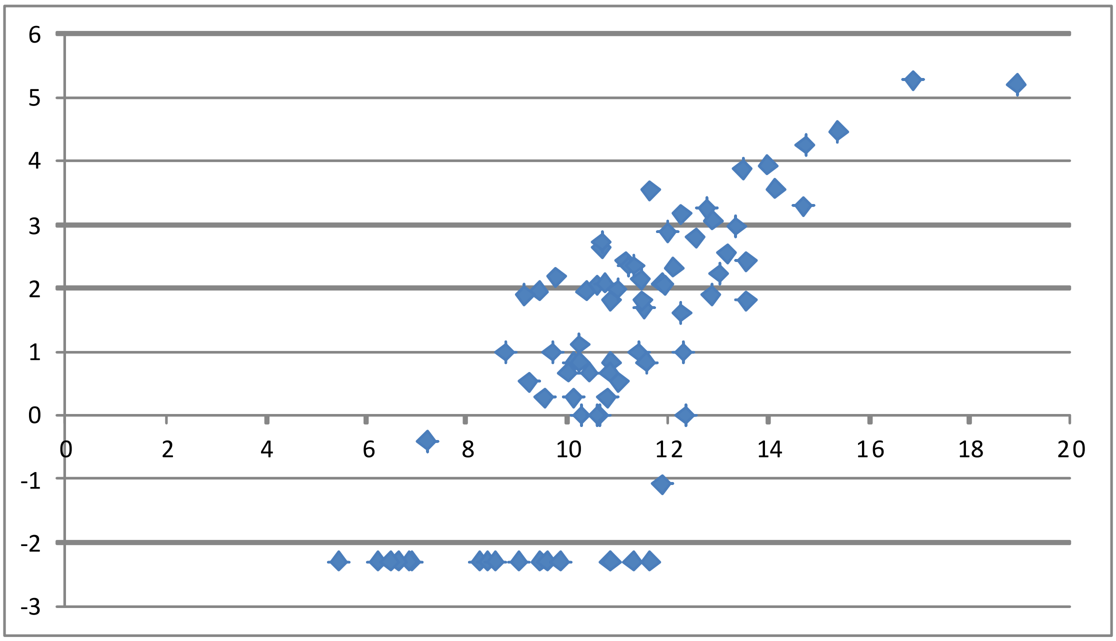
$teh11_i$ – the average number of technologies created in a region in a year (in the period since 2009 till 2011);

$teh12_i$ – the average number of technologies created in a region in a year (since 2010 till 2012).

2.3 The results of empirical analysis

Figure 1 shows the dependence in the logaryphms of $teh12_i$ of the created technological innovations from size $\overline{V}_i$ of the overall space of innovations in 80 regions of the Russian Federation for the period of 2010-2012. The dependence we observe here confirms the expediency of using the exponential production function in building the stochastic frontier for the production capacities.

Figure 1. Dependence of the number of created technological innovations $teh12_i$ (vertical axis) from the volume $\overline{V}_i$ of the overall space of region's innovations (horizontal axis), data as of 2010-2012 in the logariphmic form



In order to test further the statistical hypothesis $H_0^1 : \eta^2 = 0$ we calculate the parameters of the model:

$$\ln Q_i = c + \delta \ln \overline{V}_i + \eta B_i + v_i - u_i \ . \qquad (3)$$

In the third, fourth and fifth lines of Table 2 we present the estimates for δ , c and η for the parameters of the model (3), which were calculated using the maximum likelihood

[4]Averaging is applied since smoothing of input data is expedient here

method. In the sixth line of Table 2 we present the overall result of testing the hypothesis $H_0^2 : \sigma_u^2 = 0$ - there is no inefficiency (see also Aivazya, Afanasiev, 2014). And the seventh line is the maximum value of the likelihood function logarithm. In the models built separately for the years 2010, 20122 and 2012 the estimate η is insignificantly different from zero at the 10% level. The statistical hypothesis H_0^1 is thus not rejected[5]. And we accept the Hypothesis 1: the number of technological innovations created by a region is predetermined by the volume of the overall space of innovations.

Table 2. Parameters' estimates for the model (3)

Estimates	Model (3) for $teh10$	Model (3) for $teh11$	Model (3) for $teh12$
(1)	(2)	(3)	(4)
δ	.7814***	.7140***	.6808***
c	-5.7531***	-4.9016***	-4.4133***
η	-.1993	-.1710	-.1380
$H_0^2 : \sigma_u^2 = 0$	rejected	rejected	rejected
Log likely	-116.56	-124.66	-130.83

In the second, third and fourth columns of Table 3 we have the estimates for δ and c for the model (2), according to the data as of 2010-2012. And in the seventh and eighth lines we have the calculated values for c/δ and $\overline{w}$, accordingly.

Table 3. Parameters' estimates for the models (2) and (4)

Estimates	Model (2) for $teh10$	Model (2) for $teh11$	Model (2) for $teh12$	Model (4) for 2010-2012
(1)	(2)	(3)	(4)	(5)
δ	.6832***	.6465***	.6170***	.6816***
c	-5.2781***	-4.7775***	-4.1406***	-5.2571***
δ_0				-.0355*
c_0				.5618*
$H_0^2 : \sigma_u^2 = 0$	rejected	rejected	rejected	rejected
Log likely	-116.72	-125.16	-130.88	-375.62
c/δ	-7.7249	-7.3889	-6.7107	
$\overline{w} = e^{c/\delta}$	4.42E-04	6.18E-04	1.22E-03	
growth $\overline{w}$ by %		39.9	97.1	

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[5] Positive and statistically meaningful estimate of the influence of δ in the model (3) can be accompanied by the insignificant influence of η due to possible multicolinearity effect. For additional testing of H_0^1: $\eta^2 = 0$ against the alternative hypothesis $H_A^1 : \eta^2 > 0$ we can use the statistics $Lr = 2(\ln L(H_1^A) - \ln L(H_1))$, where $L(H_1^A)$ is the value of the likelihood function under the alternative hypothesis and $L(H_1)$ is the value of the likelihood function for H0. Previously, in (Aivazyan et al., 2012) it was also shown that if under the given level of significance α the value of test statistics Lr is above $\chi^2_{2\alpha}(1)$ -quantile of the level 2α $\chi^2(1)$ distribution, the H_0^1 should be rejected.

Then we test both hypotheses.

Hypothesis 2: elasticity of δ for the number of created innovations by the volume of overall space of innovations is constant in time.

Hypothesis 3: the constant c in the model (2) is constant in time.

In order to test the hypotheses 2 and 3 we build the dynamic model using the data for the years 2010-2012:

$$\ln Q_{it} = c + c_0 t + (\delta + \delta_0 t)\ln \overline{V}_{it} + v_{it} - u_{it} \quad (4)$$

Row 5 of Table 3 presents the results of estimating the parameters of the model (4). Estimation of the parameter δ_0 in the model (4) is significant at the 10% level. Hypothesis 2 is rejected in favor of the alternative hypothesis: elasticity δ of the number of created technological innovations by the volume of the overall space of innovations is decreasing in time. Estimate of the parameter c_0 of the model (4) is significant at the 10% level. Hypothesis 3 is rejected in favor of the alternative one: the constant c in the model (2) is growing in time. Despite the fact that the estimate δ is decreasing, and significantly, the ratio c/δ is growing. As a result, we also observe the growth of $\overline{w} = e^{c/\delta}$. In the last line of Table 3 we demonstrate the growth of $\overline{w}$ in %. Thus, we can make the conclusion that the share, used by the efficient regions, in the overall space of innovations is increasing.

For each of the 80 regions we get the estimates of efficiency $TE_i = E(e^{-u_i} / v_i - u_i)$ from using the overall space of innovations for creation of own technological innovations. These estimates of efficiency TE_i^{2010} for the year 2010, TE_i^{2011} for 2011 and TE_i^{2012} for 2012 are presented accordingly in columns 5, 6 and 7 of Table P1 in the Appendix below.

Figure 2a. Each dot stands for a region in the overall space of efficiency estimates. Horizontal axis – the estimates for TE_i^{2010}, vertical axis – the estimates for TE_i^{2011}.

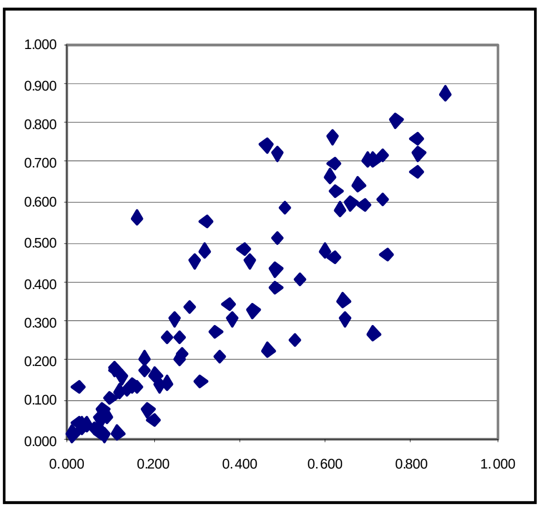
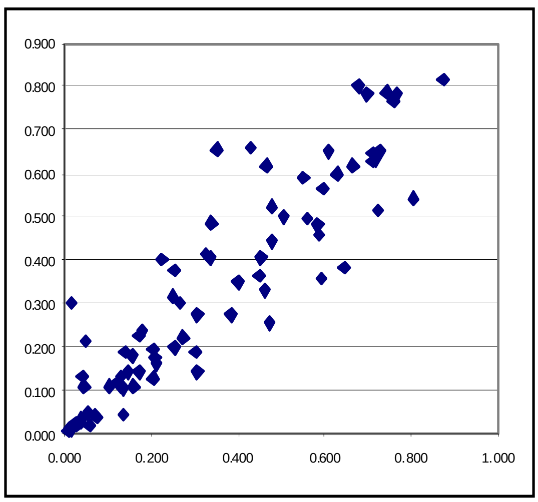


Figure 2b. Each dot describes the region in the space of efficiency estimates. Horizontal axis – the estimate of TE_i^{2011}, vertical axis – the estimate of TE_i^{2012}.



In Figure 2a each dot describes a particular region in the space of efficiency estimates' values. Horizontal axis – estimate of the region TE_i^{2010} for the year 2010, vertical axis – estimate of TE_i^{2011} for the year 2011. The correlation coefficient for these estimates is 0.8876. Efficiency estimates for the next two years demonstrate strong dependence. In Figure 2b the horizontal axis gives the estimate of TE_i^{2011} for the year 2011, and the vertical axis shows the estimate of TE_i^{2012} for the year 2012. The correlation coefficient for these estimates is 0.8959. Here we also get strong interdependence of the efficiency estimates which preconditions the stability of efficiency ranking of the regions in time. Efficiency estimates for the use of innovations space are important indicators of regional innovative activity, adding an extra feature to regions' technological efficiency as presented in (Makarov et al., 2014). The estimates $\tilde{V}_i = \tilde{w}_i \overline{V}_i$ for the volume of innovations' space, used by all 80 regions of the Russian Federation for creation of new technologies as of 2012 are presented in columns 2-4 of Table P1 in the Appendix.

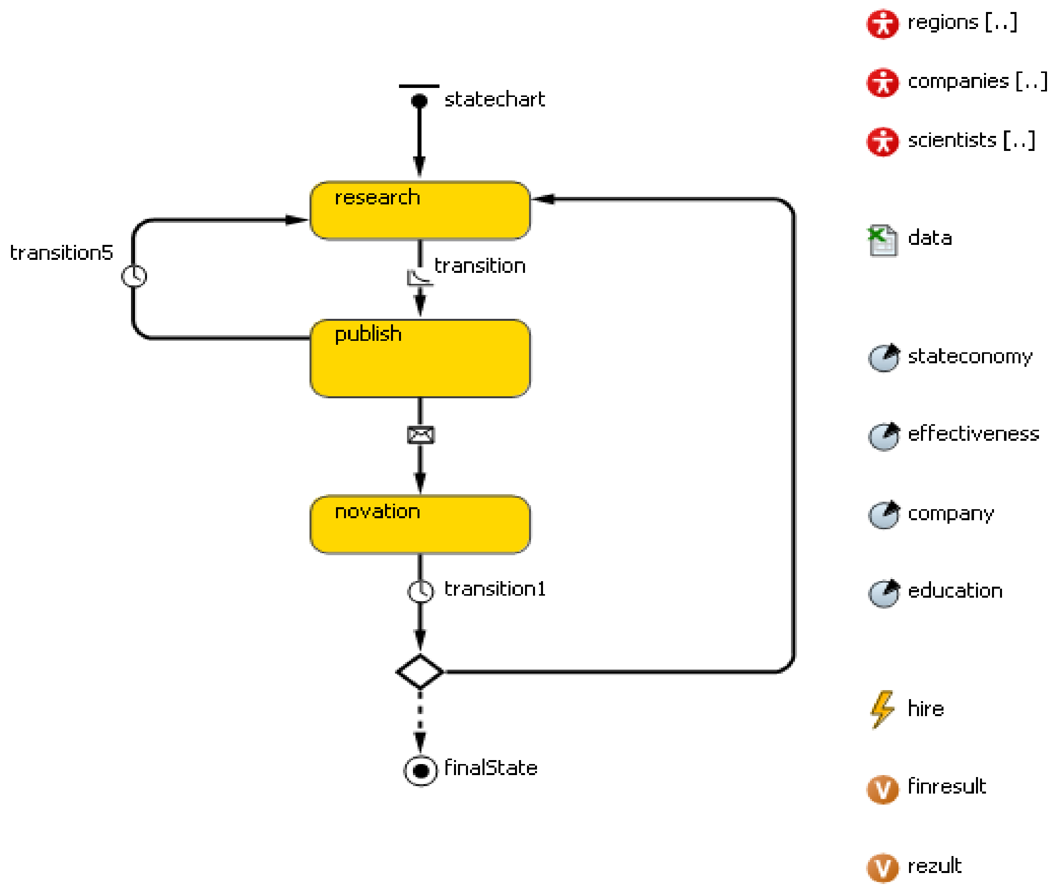
3. THE MODEL OF INNOVATIONS' CREATION

In order to study the processes of creation and spread of new knowledge we have designed an agent-oriented model (AOM) estimating the innovative activity of Russian regions. The result of imitation became the process of technological innovations' creation which predetermines the capacities and opportunities for further intensive development of regions in Russian Federation. Creation of innovation is considered here as a result of science and business interaction under the conditions set and regulated by the state. This vision is very much similar to the popular concept of innovation development by Henry Etzkowitz (2010) which mentions, inter alia, strengthening the horizontal connections between business and university science. Dynamics and quality of their interaction must be supported and promoted by means of increased decentralization of decision-making processes with the emphasis on joint initiatives.

Taking into account the specificity of research process organization in Russia, as a source innovations here we consider a research group performing scientific activity in a research organization. The result of their research activity is an intellectual product, including publications and/or patents etc. Innovatively active enterprises of a region estimate the real opportunities for these research results' further implementation in their productions. In case of a favourable estimation an enterprise is turning to a particular research organization with a proposition of cooperation. The result from this cooperation is the development of an experimental sample – a prototype of a technological innovation. In the process of its development an enterprise also carries out marketing research so that to evaluate the potential economic efficiency from this innovation implementation. If this evaluation is favorable – this means that innovation can be implemented full-scale with a certain economic effect.

Intensity of innovations at the regional level is determined by the volume of the overall innovation space used. And this volume depends on the volume of the overall available scientific space and the share of technological innovations specifically. The volume of the overall space of innovations in a particular region can be estimated using the official statistics data. There are three types of agents in this model: regions (agents of upper level), enterprises and research teams. Figure 3 shows the conditions in which a particular agent (scientist/researcher) can be in the process of innovations' creation. The possible conditions of this agent are as follows: research = the process of a research study being carried out; publish = the state of readiness for interaction with the ordering enterprises after publication of research results; novation = creation of an experimantel sample in full interaction with an ordering enterprise; finslState = experimental sample is passed over to the stage of full-scale production, thus, an innovation emerges.

Figure 3. Model specification in AnyLogic[6]



Description of the transitions:

- Statechart research – the agent "scientist" enters the state "research", which is the beginning of the imitation process;
- transition – transition from the stage "research" to the stage "publish". Time of this transition can be random. All key features of this transition depend on the research efficiency and also on the efficiency of management at the regional level;
- transition from the stage "publish" to the stage "novation". It starts with an invitation which can be from one of the regional enterprises, and in many cases this invitation is quite a random phenomenon. If a research team gets this invitation and accepts it – it starts the implementation of its research results into the real production practice of this enterprise. Features of this transition depends on how truly innovatively active this enterprise is and also they partially depend on the efficiency of regional administration overall;
- transition from the stage "publish" to the stage "research". If a research team does not get any such invitation from a company or an enterprise, it automatically returns to further research search – the stage "research". Time spent by a research team at the stage "pub-

[6] AnyLogic – the instrument of imitation modeling which supports all approaches to imitation models' design: process-oriented (discrete event), system dynamic and also agent one, or any combination of them. More details can be found at http://www.anylogic.ru.

lish" is again a random value, though partially it can be explained by the efficiency of management at the regional level;

- transition from the stage "novation" to the stage" finslState". Successul implementation of the research result is the final stage in the process of innovation creation. Probability of transition to this stage is predetermined by the efficient performance of innovatively active enterprises and also by efficient management at the regional level;
- transition from the stage "novation" to the stage "research" is taking place if the attempt to implement the research results is not successful at all, which means innovation is not born.

Efficiency of regional management can be described using the estimates of technical efficiency by regions of the Russian Federation, obtained from the model of production potential, presented earlier in (Makarov et al., 2014). Innovative activity of regions is described by the volume of space of technological innovations (see the indicators in columns 2-4 of Table P1 in the Appendix). Volume of this space of technological innovations can be determined knowing the volume of the overall space of innovations in a region and also the share of this overall space, used in creation of technological innovations. The dynamics of changes in the innovations space is determined for each region using the forecasted data on potential changes in the overall space of innovations and in the share used by a particular region for creation of technological innovations. Using this model, we can simulate the process of innovations' creation by region and thus evaluate the potential impact of regional development features on the intensity of innovations' development by regions.

Figure 4a. Intensity of innovations' creation in a region with relatively large innovation space. On the horizontal axis – simulation time; on the vertical axis – the number of created innovations.

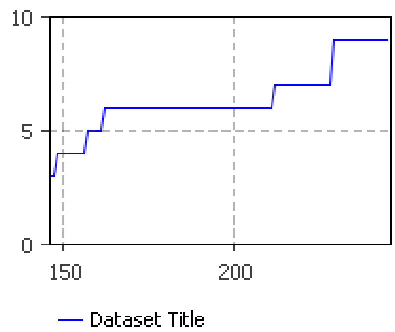
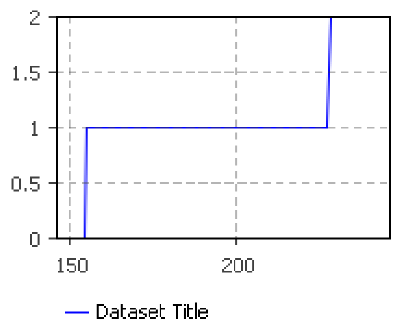


Figure 4b. Intensity of innovations' creation in a region with relatively small volume of the innovation space. On the horizontal axis – simulation time; on the vertical axis – the number of created innovations.



Figures 4a and 4b demonstrate the intensities of technological innovations' creation for the regions with relatively large (small) innovation space. Verification of the model is oriented on the development of a methodology for further state regulation over the process of knowledge economy formation in which macro- and mezolevels must be coordinated and correlated.

4. CONCLUSIONS

Approach used in this study to explain the process of knowledge economy formation in the region of Russian Federation focuses on the important resource used in the production of innovations – the totality of potential relations between research organizations and innovatively active enterprises of the regions in question.

The authors demonstrate, using the data for the years 2010-2012, that the elasticity in the numbers of production technologies created in the regions according to the number of research institutions in them is not significantly different from the elasticity in the number of production technologies by the number of innovatively active enterprises in a region.

The key factor for the number of new production technologies created by the regions is the volume of the overall space of innovations which is determined knowing the number of potential connections between research organizations and innovatively active enterprises.

Our research results do not contradict the hypothesis that the number of new production technologies created in a region depends on the volume of the overall space of innovations and the efficiency of its use.

During the period since 2010 and till 2012 the share in the overall space of innovations used by the innovatively active regions for creation of technological innovations was growing. For each year separately we calculated the estimates of the volume of overall space of innovations, used by Russian Federation regions for creation of new production technologies.

The obtained results prove the important role of regional authorities in stimulation of cooperation between the state, business and research & education community in the context of regional innovation systems' development. This influence of regional authorities may be aimed at increasing the overall space of innovations in a particular region, or at emphasizing the efficiency of this space use during the creation of innovations onf a particular type.

In order to study the processes of new knowledge generation and spread we have built an agent-oriented model to evaluate the innovative activity of Russian Federation regions. The modelled process of technological innovations' creation as a result of cooperation between research institutions and innovatively active enterprises is determined by the totality of regional economic features, including: the volume of the space of technological innovations in a region; the volume of the overall space of innovations in a region and its separate share used in production of technological innovations in a region.

Appendix

Table P1.

Estimates of the technological innovations' space (columns 2-4) and of the efficiency of using the overall volume of innovations' space (columns 5-7)

	$\tilde{V}_i$ 2010	$\tilde{V}_i$ 2011	$\tilde{V}_i$ 2012	TE_i^{2010}	TE_i^{2011}	TE_i^{2012}
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Belgorodskaya oblast'	18.587	26.421	34.315	0.812	0.76	0.769
Bryanskaya oblast'	9.197	17.81	23.376	0.736	0.718	0.632
Vladimirskaya oblast'	14.898	6.62	19.06	0.53	0.249	0.314
Voronezhskya oblast'	59.947	78.764	103.936	0.635	0.582	0.482
Ivanovskaya oblast'	1.212	6.724	20.214	0.162	0.559	0.495
Kaluzhskaya oblast'	30.483	43.397	99.066	0.879	0.873	0.814
Kostromskaya oblast'	2.044	1.181	3.955	0.641	0.353	0.655
Kurskaya oblast'	0.046	0.245	2.167	0.024	0.04	0.131
Lipetskaya oblast'	0.046	0.671	1.358	0.028	0.131	0.133
Moskovskaya oblast'	460.693	956.31	1583.051	0.409	0.48	0.445
Orlovskaya oblast'	5.809	5.159	4.958	0.618	0.46	0.329
Ryazanskaya oblast'	0.683	1.93	3.096	0.113	0.171	0.14
Smolenskaya oblast'	5.584	2.635	2.108	0.647	0.302	0.19

Tambovskaya oblast'	0.681	0.04	0.039	0.12	0.017	0.011
Tverskaya oblast'	5.778	4.534	6.528	0.352	0.209	0.173
Tul'skaya oblast'	8.757	10.112	34.847	0.375	0.34	0.484
Yaroslavskaya oblast'	16.891	19.004	52.712	0.432	0.325	0.413
g, Moskva	2304.145	3934.007	6415.534	0.12	0.121	0.118
Respublika Kareliya	0.253	0.242	5.179	0.079	0.05	0.212
Respublika Komi	0.685	1.234	3.998	0.108	0.178	0.237
Arkhangel'skaya oblast'	22.089	22.884	41.637	0.734	0.607	0.652
Vologodskaya oblast'	2.508	1.951	4.07	0.231	0.14	0.188
Kaliningradskaya oblast'	4.534	5.913	7.257	0.679	0.644	0.381
Leningradskaya oblast'	11.66	16.601	26.15	0.611	0.663	0.615
Murmanskaya oblast'	0.048	0.04	0.039	0.014	0.014	0.011
Novgorodskaya oblast'	3.431	5.23	10.273	0.622	0.697	0.781
Pskovskaya oblast'	3.061	2.578	2.047	0.486	0.383	0.272
g, Sankt-Peterburg	1150.927	2743.222	6034.485	0.284	0.336	0.407
Respublika Adygeya	0.043	0.037	0.035	0.076	0.055	0.048
Respublika Kalmykiya	0.041	0.035	0.032	0.267	0.212	0.16
Krasnodarskiy kray	24.805	42.081	78.579	0.249	0.304	0.275
Astrakhanskaya oblast'	11.609	13.711	14.453	0.615	0.767	0.781
Volgogradskaya oblast'	2.643	1.314	0.264	0.091	0.058	0.018
Rostovskaya oblast'	34.521	49.317	67.456	0.232	0.255	0.197
Respublika Dagestan	16.186	11.074	26.254	0.763	0.804	0.541
Respublika Ingushetiya	0.041	0.035	0.033	0.205	0.16	0.108
Kabardino-Balkarskaya Respublika	2.316	4.606	5.662	0.508	0.586	0.456
Karachayevo-Cherkesskaya Respublika	0.042	0.036	0.033	0.138	0.126	0.112
Respublika Severnaya Osetiya - Alaniya	0.045	0.038	0.036	0.036	0.036	0.031
Chechenskaya Respublika	0.041	0.035	0.033	0.263	0.202	0.129
Stavropol'skiy kray	0.048	0.041	0.04	0.013	0.01	0.007
Respublika Bashkortostan	16.682	20.068	25.166	0.162	0.13	0.107
Respublika Mariy El	0.045	0.038	0.037	0.044	0.036	0.024
Respublika Mordoviya	6.54	11.903	19.157	0.817	0.725	0.65
Respublika Tatarstan	47.622	81.455	261.866	0.179	0.173	0.225
Udmurtskaya Respublika	5.887	11.677	35.67	0.262	0.254	0.376
Chuvashskaya Respublika	16.388	17.393	22.625	0.69	0.592	0.356
Permskiy kray	59.635	105.258	150.129	0.295	0.448	0.363
Kirovskaya oblast'	0.694	0.041	0.04	0.086	0.011	0.008
Nizhegorodskaya oblast'	356.293	409.947	569.755	0.657	0.596	0.567
Orenburgskaya oblast'	8.879	3.642	5.336	0.309	0.148	0.141
Penzenskaya oblast'	16.387	15.005	41.563	0.741	0.467	0.616
Samarskaya oblast'	102.141	133.777	156.808	0.489	0.507	0.501
Saratovskaya oblast'	47.392	49.843	94.334	0.712	0.709	0.628
Ul'yanovskaya oblast'	6.533	18.636	35.529	0.461	0.741	0.785
Kurganskaya oblast'	0.253	0.04	3.906	0.078	0.018	0.302
Sverdlovskaya oblast'	232.885	592.361	1062.763	0.32	0.477	0.522
Tyumenskaya oblast'	44.015	46.814	48.776	0.344	0.275	0.224
Chelyabinskaya oblast'	126.056	241.501	432.767	0.701	0.709	0.644
Respublika Altay	0.044	0.039	0.037	0.066	0.024	0.022
Respublika Buryatiya	7.256	2.658	5.015	0.711	0.265	0.302
Respublika Tyva	0.612	0.751	0.561	0.49	0.722	0.513

Respublika Khakasiya	0.043	0.037	0.035	0.081	0.071	0.045
Altayskiy kray	5.111	6.852	6.785	0.151	0.136	0.102
Zabaykal'skiy kray	0.659	0.229	0.035	0.212	0.135	0.041
Krasnoyarskiy kray	33.851	94.745	184.217	0.323	0.55	0.587
Irkutskaya oblast'	38.744	30.549	130.824	0.486	0.427	0.66
Kemerovskaya oblast'	18.293	26.684	43.465	0.624	0.629	0.597
Novosibirskaya oblast'	109.523	261.62	394.804	0.422	0.452	0.405
Omskaya oblast'	25.345	20.193	33.751	0.54	0.402	0.351
Tomskaya oblast'	10.309	16.298	17.936	0.177	0.206	0.193
Respublika Sakha (Yakutiya)	1.825	0.244	1.378	0.199	0.046	0.109
Kamchatskiy kray	0.249	0.68	1.376	0.101	0.103	0.11
Primorskiy kray	5.164	13.469	28.742	0.126	0.155	0.18
Khabarovskiy kray	7.001	2.858	1.484	0.187	0.073	0.039
Amurskaya oblast'	0.045	0.039	0.037	0.036	0.027	0.019
Magadanskaya oblast'	4.955	9.253	8.047	0.812	0.678	0.801
Sakhalinskaya oblast'	1.119	0.651	2.765	0.467	0.223	0.4
Yevreyskaya avtonomnaya oblast'	0.039	0.034	0.032	0.385	0.305	0.14
Chukotskiy avtonomnyy okrug	0.035	0.032	0.031	0.597	0.474	0.255

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